Surfactant Spectator

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Surfactant Spectator is electronic newsletters in the field of Surfactant Chemistry, placed on the web four times a year. We welcome comments, articles and information on the content of this newsletter.

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Editor's note:

This edition of the Surfactant Spectator begins to look at the interactions of various surfactant ingredients in formulations. Since formulations contain a variety of materials including surfactants, actives, builders and polymers, the performance is determined by the interactions of the various raw materials with each other and not the properties of the individual additives in water. Despite this most surfactant manufacturers publish data on surfactant properties neat in water.

The article attached relates the classical concept developed by Pearson related to hardness and softness of acids and bases to anionic and cationic surfactants. The proper selection of these materials allows the formulator to capitalize on this interaction and pick raw materials that will provide viscosity without traditional thickeners.

The next editions will address anionic / amphoteric interactions as we continue to address interactions.

The Surfactant Spectator® solicits articles from members of the technical community for publication.

Thomas G. O'Lenick Editor

Fatty Quats - Hardness of Cationic Materials

Thomas G. O'Lenick
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Background

Fatty quaternaries have been known for many years. Because of their fatty nature and positive charge, these compounds find application in a variety of areas including as conditioners for hair and skin. Despite the fact these materials have been recognized as key cosmetic additives, there is little published on the structure function relationship on basic properties. For example, some quats are very insoluble when added to anionic surfactant, others have improved compatibility. The ability to select quats that have optimum compatibility with anionic systems offers the formulator flexibility in formulating heretofore unavailable. There is also much confusion related to deposition of cationic material onto hair as measured by a number of red dye uptake tests. These tests merely measure cationic on the surface of the hair. Since deposition on hair made from a solution containing cationic and anionic, contains no free cationic, no red color is observed with these tests. This does not mean however there was no deposition, it simply means the deposited material does not have an overall positive charge and consequently does not bind dye.

Anyone that has added stearylalkonium chloride to sodium lauryl sulfate and observed the white sticky solid that results knows anionic and cationic surfactants can be incompatible. We have begun to call anionic and cationic materials that produce a white gunky solid when mixed together *hard complexes.* As the expression implies the cationic and anionic compound possess properties which when added together form insoluble complexes (salts). We set out to determine if there are cationic materials having different structures which could be more soluble in the presence of anionic surfactants. The terms used here for quats and anionic materials are an adaptation of the work of Pearson used to describe acids and bases. Pearson proposed that "hard acids bind strongly to hard bases and soft acids bind softly to soft bases"[1]

The structural changes that can be made to cationic molecules can "soften" them, making them more compatible with anionic systems. Alternatively, there should also be the possibility of developing an anionic material that has increased compatibility with cationic surfactants, perhaps a more highly ethoxylated sulfate or a sulfosuccinate. However, this concept of modifying the anionic, is a topic for another investigation.

A study was undertaken to determine (1) compatibility of specific quats with SLS and SLES, (2) foam properties of the combinations with SLS and SLES (3) substantivity of these combinations with SLS and SLES and (4).

The quats studied conform to the following structure:

$$\begin{array}{c} R^2 \\ | \\ R^1\text{-}N^+\text{-}R^3 \\ | \\ R^2 \end{array} \qquad Cl^-$$

The preferred definitions for the study groups are:

R^1 1. Alkyl (C12)
Ricinoleylamidopropyl
Dilinoleylamidopropyl
Cocamidopropyl

R^2 1. Methyl $-CH_3$
2. 2-hydroxy ethyl $-CH_2CH_2OH$

R^3 1. Methyl $-CH_3$
2. Benzyl $-CH_2\text{-}C_6H_5$
3. Glyceryl $-CH_2\text{-}CH(OH)\text{-}CH_2\text{-}OH$

Table 1 Compounds Studied

Name	**R^1**	**R^2**	**R^3**	**Description**
AMB	Alkyl (C12)	CH_3	Benzyl	Coco dimethyl benzyl ammonium chloride
AME	Alkyl (C12)	CH_2CH_2OH	CH_3	Coco di-2 hydroxyethyl methyl ammonium chloride
AMG	Alkyl (C12)	CH_3	Glyceryl	Coco dimethyl glyceryl ammonium chloride
AMM	Alkyl (C12)	CH_3	CH_3	Coco tri-methyl ammonium chloride
AEB	Alkyl (C12)	CH_2CH_2OH	Benzyl	Coco di-2 hydroxyethyl benzyl ammonium chloride
AEG	Alkyl (C12)	CH_2CH_2OH	Glyceryl	Coco di-2 hydroxyethyl glyceryl ammonium chloride
CaMB	Castor Amido	CH_3	Benzyl	Ricinoleylamidopropyl dimethyl benzyl ammonium chloride
CaMG	Castor Amido	CH_3	Glyceryl	Ricinoleylamidopropyl dimethyl glyceryl ammonium chloride
DMB	Dimer Amido	CH_3	Benzyl	Dilinoleylamidopropyl dimethyl benzyl ammonium chloride
DMG	Dimer Amido	CH_3	Glyceryl	Dilinoleylamidopropyl dimethyl glyceryl ammonium chloride
DMM	Dimer Amido	CH_3	CH_3	Dilinoleylamidopropyl trimethyl ammonium chloride
MMB	Cocamido	CH_3	Benzyl	Cocamidopropyl dimethyl benzyl ammonium chloride
MMG	Cocamido	CH_3	Glyceryl	Cocamidopropyl dimethyl glyceryl ammonium chloride
MMM	Cocamido	CH_3	CH_3	Cocamidopropyl trimethyl ammonium chloride

(A) Compatibility with Anionic

A determination of compatibility of a variety of quats with two anionic surfactants, sodium lauryl sulfate and sodium laureth-3-sulfate was made. The compatibility was determined by titration. The point at which an anionic solution containing 10% anionic either became hazy formed a precipitate was determined.

PROCEDURE- Solution preparation

Prepare 50g of a 10% active test solution of surfactant. Record pH.

SURFACTANTS-

Sodium Lauryl Sulfate

Sodium Laureth Sulfate

Ingredient	W/W
Surfactant	34.00%
Distilled Water	65.50%

Combine ingredients listed with slow to medium agitation. Mix until uniform at

20-25^{o}C. Prepare test solutions for both SLS and SLES.

10% active SLS

10% active SLES

Prepare 100g of a 10% active test solution for each quat sample.

Preparation of 10% Active Quat

Ingredient	W/W
Stock Quat Solution (35% w/w)	28.50%
Distilled Water	71.50%

Combine ingredients listed with slow to medium agitation. Mix at 20-25^oC until uniform.

Using a hot plate and stir bar set on medium agitation, slowly titrate surfactant test solution with quat solution using a 5mL disposable pipette, at a rate of one drop per second. Continue adding quat solution until a precipitate is observed. (Subjective evaluation). Solution will appear cloudy and translucent at this point. Record the amount (grams) of quat solution added at the cloud point, final pH, and the viscosity. Repeat for remaining quat solutions. Store at 20-25^oC for use in part II. Observe Solutions after 24 hours. If solution remains cloudy, then titration is complete. If solution is clear, then repeat step 3. Perform titration for each quat using SLS and SLES individually.

CALCULATIONS

$$\% \text{ QUAT ADDED} = \frac{\text{GRAMS OF QUAT ADDED}}{(50 + \text{GRAMS OF QUAT ADDED})} \times 100$$

RESULTS

Table 2: Titration Data (SLS)

Quat Sample	Amount of quat solution added to achieve haze point in SLS (g)	Final pH	Viscosity (cps)	Notes
AMB	9.75	7.6	4,400	Formed an opaque, pearlescent gel beyond the haze point
AME	6.28	7.1	<10	Did not form a gel
AMG	30.49	8.1	<10	Did not form a gel
AMM	17.63	7.8	<10	Did not form a gel
AEB	14.58	7.9	<10	Did not form a gel
AEG	29.53	7.7	<10	Did not form a gel
CaMB	25.72	7.6	1,000	Formed a gel
CaMG	44.47	7.1	1,000	Formed a gel
DMB	18.33	7.6	<10	Did not form a gel
DMG	40.25	7.6	12,000	Formed a gel
DMM	23.85	7.6	6,000	Formed a gel
MMB	15.28	7.4	14,000	Formed a
MMG	31.02	8.0	13,000	Formed a gel
MMM	21.25	8.0	13,400	Formed a gel

TABLE: 3 Titration Data (SLS)

Hard Quats – No Gel in Sodium Lauryl Sulfate

Quat Sample	Amount of quat solution added to achieve haze point in SLS (g)	Viscosity (cps)	Notes
AMB	9.75	<10	Did not form a gel
AME	6.28	<10	Did not form a gel
AEB	14.58	<10	Did not form a gel
AMM	17.63	<10	Did not form a gel
DMB	18.33	<10	Did not form a gel
AEG	29.53	<10	Did not form a gel
AMG	30.49	<10	Did not form a gel

Soft Quats – Gel Formers in Sodium Lauryl Sulfate

Quat Sample	Amount of quat solution added to achieve haze point in SLS (g)	Viscosity (cps)	Notes
MMB	15.28	14,000	Formed a gel
MMM	21.25	13,400	Formed a gel
DMM	23.85	6,000	Formed a gel
CaMB	25.72	1,000	Formed a gel
MMG	31.02	19,200	Formed a gel
DMG	40.25	12,000	Formed a gel

The quats that showed the best compatibility and gellation properties with sodium lauryl sulfate were the amido quats. The only exception was the amido quat that contained an aromatic group (DMB).

Table : 4 Titration Data (SLES)

Quat Sam-ple	Amount of quat solution added to achieve haze point in SLS (g)	Final pH	Viscosity (cps)	Notes
AMB	18.67	6.6	<10	Did not form a gel
AME	4.47	7.0	<10	Formed a gel
AMG	25.04	7.2	1,000	Formed a gel
AMM	17.44	7.2	<10	Did not form a gel
AEB	18.35	7.2	<10	Did not form a gel
AEG	38.72	7.1	1,000	Formed a gel
CaMB	24.31	7.6	1,000	Formed a gel
CaMG	46.23	7.3	1,000	Formed a gel
DMB	11.09	7.3	<10	Did not form a gel
DMG	28.37	7.9	6,800	Formed a gel
DMM	20.00	7.0	6,200	Formed a gel
MMB	25.00	7.1	<10	Formed a gel.
MMG	26.68	7.1	40,000	Formed a gel
MMM	20.23	7.3	50,000	Formed a gel

TABLE: 5 Titration Data (SLS)

Hard Quats – No Gel in Sodium Laureth-3-Sulfate

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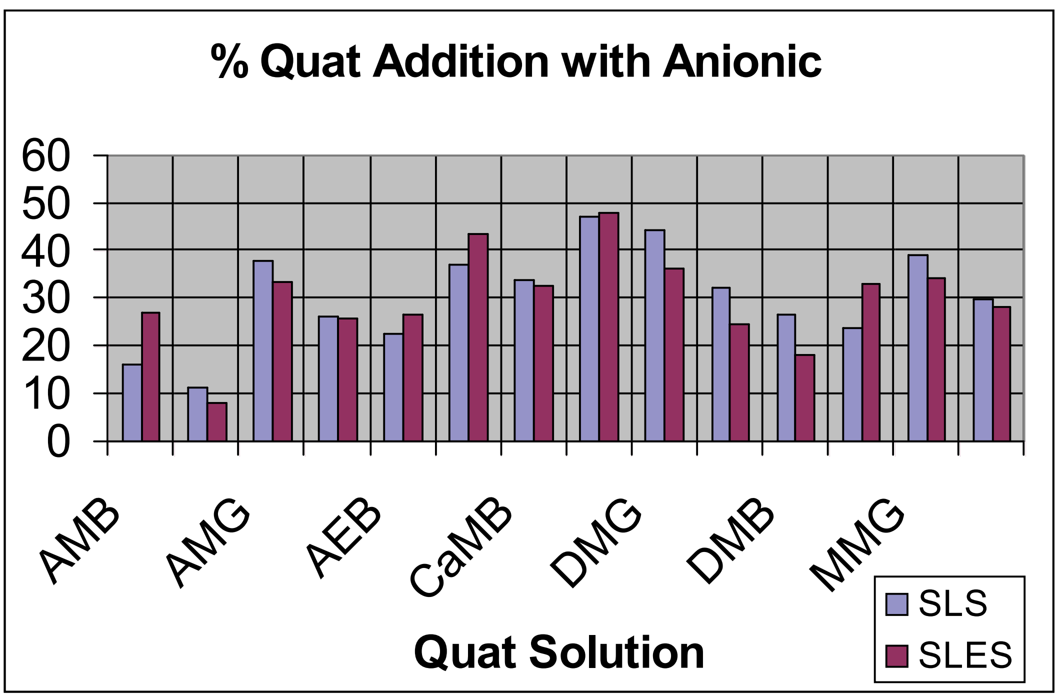
Quat Sam-ple	Amount of quat solution added to achieve haze point in SLS (g)	Viscosity (cps)	Notes
AMB	18.67	<10	Did not form a gel
AMM	17.44	<10	Did not form a gel
AEB	18.35	<10	Did not form a gel
DMB	11.09	<10	Did not form a gel

Soft Quats – Gel in Sodium Laureth-3-Sulfate

Quat Sample	Amount of quat solution added to achieve haze point in SLS (g)	Viscosity (cps)	Notes
AME	4.47	7,000	Formed a gel
DMM	20.00	6,200	Formed a gel
MMM	20.23	50,000	Formed a gel
CaMB	24.31	1,000	Formed a gel
AMG	25.04	1,000	Formed a gel
MMB	25.00	9,800	Formed a gel
MMG	26.68	40,000	Formed a gel
DMG	28.37	6,800	Formed a gel
AEG	38.72	1,000	Formed a gel
CaMG	46.23	1,000	Formed a gel

There was improved compatibility with sodium laureth-3-sulfate when compared to sodium lauryl sulfate. This leads to the conclusion that SLES is a softer anionic than SLES.

Graph 1



All quat compounds reached a cloud point when titrated into anionic. However the amount necessary to reach the haze point was different and the nature of the end point were different. The so-called hard quats have very little tolerance for anionic, forming insoluble precipitates with very little addition. Quaternary compounds having intermediate hardness show compatibility with anionic surfactants at near stoichiometric amounts, but do eventually haze. Soft quats do not exhibit a haze, but rather show a clear gel.

(B) FOAM HEIGHT AND STABILITY

It has been generally assumed that a gel made using an anionic and cationic combination would not foam. An evaluation of the gelled system was therefore undertaken to see if this is true.

PURPOSE

Determine the height and stability of foam produced from aqueous solutions of anionic surfactant containing quaternium compounds.

PROCEDURE

QUAT SOLUTIONS

TITRATED QUAT SOLUTIONS FROM PART I ABOVE

CONTROLS

INCI: Polyquaternium-10

Sodium Lauryl Sulfate

Sodium Laureth Sulfate

Name	ARL-4-84A	ARL-4-84B	ARL-4-84C	ARL-4-84D
Polyquaternium 10	1.00%	1.00%	-	-
Deionized Water	91.00%	91.00%	92.00%	92.00%
Sodium Lauryl Sulfate	8.00%	-	8.00%	-
Sodium Laureth Sulfate	-	8.00%		8.00%

1. Prepare ARL-4-84A and B by mixing polyquaternium 10 and deionized water with a prop mixer set on low speed until uniform. (1-5min, 20-25°C).

2. Add surfactant and mix with medium agitation until uniform. (1-2min 20-25°C).

Prepare ARL-4-84C and D by combining deionized water and surfactant. Mix with medium agitation until uniform. (1-2min 20-25°C).

RESULTS

Table : 6 Foam Heights of SLS Titrations

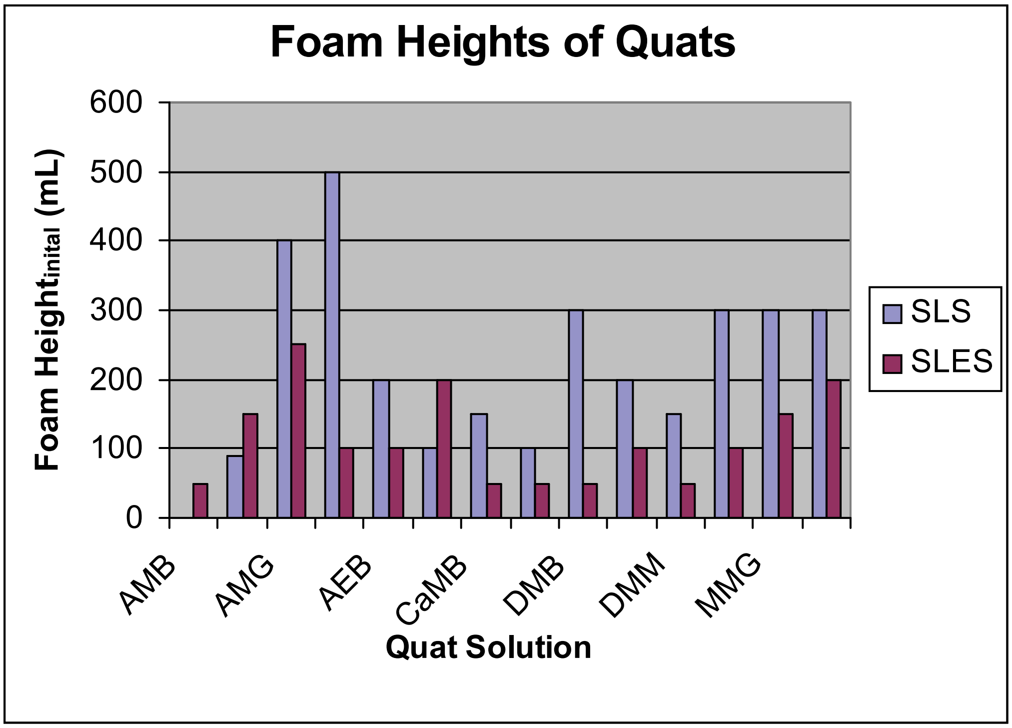
Quat Sample	Foam Height$_{max}$ (mL)	Foam Height$_{inital}$ (mL)	Foam Height$_{final}$ (mL)	Foam Stability (min)
AMB	-	-	-	Does not foam
AME	190	90	140	30.0
AMG	500	400	300	30.0
AMM	600	500	350	15.0
AEB	300	200	200	40.5
AEG	200	100	150	40.0
CaMB	250	150	175	95.0
CaMG	200	100	150	79.0
DMB	400	300	250	14.0
DMG	300	200	200	8.0
DMM	250	150	150	13.0
MMB	400	300	250	29.0
MMG	400	300	250	97.0
MMM	400	300	250	1440.0

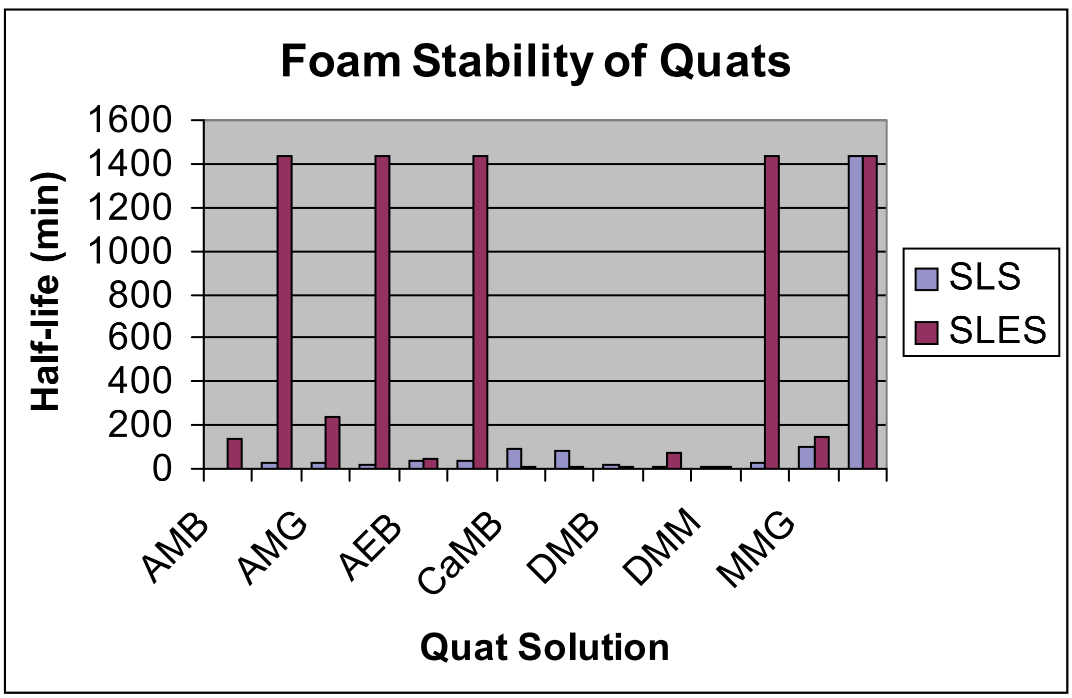
Table : 7 Foam Heights of SLES Titrations

Quat Sample	Foam Height$_{max}$ (mL)	Foam Height$_{inital}$ (mL)	Foam Height$_{final}$ (mL)	Foam Stability (min)
AMB	150	50	100	141.0
AME	250	150	175	1440.0
AMG	350	250	225	240.0
AMM	200	100	150	1440.0
AEB	200	100	150	47.0
AEG	300	200	200	1440.0
CaMB	150	50	125	8.50
CaMG	150	50	125	6.0
DMB	150	50	125	5.5
DMG	200	100	150	75.0
DMM	150	50	125	9.0
MMB	200	100	150	1440.0
MMG	250	150	175	146.5
MMM	300	200	200	1440.0

Table: 8 Foam Heights of Controls

Control	Foam Height$_{max}$ (mL)	Foam Height$_{inital}$ (mL)	Foam Height$_{final}$ (mL)	Foam Stability (min)
ARL-4-84A	200	100	100	31.0
ARL-4-84B	200	100	150	1440.0
ARL-4-84C	600	500	350	25.0
ARL-4-84D	450	350	275	180.0


Foam Heights of Quats
Foam Height$_{inital}$ (mL)
600
500
400
300
200
100
0
AMB
AMG
AEB
CaMB
DMB
DMM
MMG
Quat Solution
SLS
SLES


Foam Stability of Quats
Half-life (min)
1600
1400
1200
1000
800
600
400
200
0
AMB
AMG
AEB
CaMB
DMB
DMM
MMG
Quat Solution
SLS
SLES

Quat solutions titrated with sodium lauryl sulfate (SLS) produced higher levels of foam than those titrated with sodium laureth sulfate (SLES). However, the quat solutions that were titrated with SLES exhibited greater foam stability than those titrated with SLS. In some cases the quats titrated with SLES had a half-life greater than 24 hours (1440 minutes), including the control. After running all controls, it can be concluded that the addition of quaternium compound had a negative effect on the foaming capabilities of SLS and SLES. Stock SLS produced a foam height of 600mL, while the average foam height produced from quat/SLS was around 250mL.

Quat AMB (SLS) produced no foam. Unlike all the other quats that were titrated with SLS, which formed translucent, cloudy, gels at their respective cloud points, quat AMB produced a white, opaque paste. This is evidence that a complex is forming between this quat and SLS. This did not occur when quat AMB was titrated with SLES.

Controls for this experiment produced expected results. ARL-4-84A, which contained 1% polyquaternium 10, produced a higher foam height than ARL-4-84B, which also contained 1% polyquaternium 10, but in SLES. This also proved true for ARL-4-84C and D as well, which produced the same results. Based on these test results, SLES produced greater foam stability than SLS, however SLS produced higher levels of foam.

Quat AMM and MMM performed superior in SLS and SLES compared to all the samples tested, including the controls. AMM showed superior foaming capabilities, by achieving the greatest foam height in SLS (500 mL), as well as having one of the best foam stabilities in SLES (over 1440 minutes). This stability was roughly ten times greater than all other quats and controls tested, with the exception of AEG, CaMB, MMG, and MMM, which all had foam stabilities of over 1440 minutes. It can be concluded that these quaternium compounds did not have a great effect on the expected foaming capabilities of SLS or SLES, with the exception of AMM and MMM. These two quat solutions increased foam stability by a factor of ten without suppressing foam height.

(C) SUBSTANTIVITY (AQUEOUS DELIVERY SYSTEM)

PURPOSE

Determine the substantivity of quaternium compounds in an aqueous delivery system. To human hair.

PROCEDURE

TEST SOLUTION
STOCK SOLUTION

ARL-2-73A$_1$ LOT#: 020604

ARL-2-73A LOT#: 020604

DIRECT RED 80 (ALDRICH 365548-25G, LOT#: 04927)

GLACIAL ACETIC ACID (ALDRICH 338826-25ML, LOT #: 12405LA)

TREATMENT SOLUTIONS

Name	W/W	Formula #
35% Active Quat Solution	0.5%	ARL-4-85A-N
Deionized Water	99.5%	

CONTROL Polyquaternium-10

RESULTS

Table: 9 Cationic Substantivity: 0.5% Quat Solutions

			RESULT	
Quat Solution	Tress Sample	Treatment	Positive	Negative
AMB	A	ARL-4-85A	Pink	-
AME	B	ARL-4-85B	Purple	-
AMG	C	ARL-4-85C	-	No Color Change
AMM	D	ARL-4-85D	Purple	-
AEB	E	ARL-4-85E	Purple	-
AEG	F	ARL-4-85F	-	No Color Change
CaMB	G	ARL-4-85G	Purple	-
CaMG	H	ARL-4-85H		No Color Change
DMB	I	ARL-4-85I	Purple	-
DMG	J	ARL-4-85J	Purple	-
DMM	K	ARL-4-85K	Purple	-
MMB	L	ARL-4-85L	Purple	-
MMG	M	ARL-4-85M	Purple	-
MMM	N	ARL-4-85N	Purple	-
-	O	PositiveControl	Pink	-
-	P	Negative Control	-	No Color Change

Hair Tresses exhibiting substantivity with 0.5% Quat Solution

Positive and Negative Controls for 0.5% Quat Solutions

Hair Tresses that Exhibit Substantivity with 0.5% Quat Solution

All quat solutions, with the exception of three, (AEG, AMG, CaMG) exhibited cationic substantivity when delivered to hair tresses in a 0.5% aqueous solution. It is likely that these quat solutions did not exhibit substantivity because of their glyceryl groups. However, quat DMG, which also contained a glyceryl group, did exhibit cationic substantivity. It is also possible that the quat group was damaged, or reacted out somewhere in the study, because they were no longer cationic.

(D)_SUBSTANTIVITY (ANIONIC SURFACTANT SYSTEM)

PURPOSE

Determine the substantivity of quaternium compounds in an anionic surfactant delivery system to human hair.

PROCEDURE – STM – PE#4

QUAT SOLUTIONS

TITRATED QUAT SOLUTIONS FROM PART 1.

INCI: Polyquaternium-10

SURFACTANTS

Sodium Lauryl Sulfate

Sodium Laureth Sulfate

Lot #	Name	ARL-4-86A	ARL-4-86B	ARL-4-86C	ARL-4-86D
565720	Polyquaternium 10	0.5%	0.5%	-	-
0321605	Sodium Lauryl Sulfate	40.00%	-	40.00%	-
04107056	Sodium Laureth Sulfate	-	40.00%	-	40.00%
062906	Deionized Water	59.50%	59.50%	60.00%	60.00%

Table:10 Substantivity of Titrated Quat Solutions in SLS

		RESULT	
Tress Sample	Treatment	Positive	Negative
A	Test	-	No Color Change
B	Test	-	No Color Change
C	Test	-	No Color Change
D	Test	-	No Color Change
E	Test	-	No Color Change
F	Test	-	No Color Change
G	Test	-	No Color Change
H	Test	-	No Color Change
I	Test	-	No Color Change
J	Test	-	No Color Change
K	Test	-	No Color Change
L	Test	-	No Color Change
M	Test	-	No Color Change
N	Test	-	No Color Change
O	Positive Control	-	No Color Change
P	Negative Control	-	No Color Change

Table: 11 Substantivity of Titrated Quat Solutions in SLES

		RESULT	
Tress Sample	Treatment	Positive	Negative
A	Test	-	No Color Change
B	Test	-	No Color Change
C	Test	-	No Color Change
D	Test	-	No Color Change
E	Test	-	No Color Change
F	Test	-	No Color Change
G	Test	-	No Color Change
H	Test	-	No Color Change
I	Test	-	No Color Change
J	Test	-	No Color Change
K	Test	-	No Color Change
L	Test	-	No Color Change
M	Test	-	No Color Change
N	Test	-	No Color Change
O	Positive Control	-	No Color Change
P	Negative Control	-	No Color Change

No substantivity was observed when quat solutions were delivered from a 10% active, anionic solution of surfactant. (SLS and SLES). The test measures cationic deposition as opposed to deposition of a compound of any nature. Since the quat and anionic form a complex, the deposited material is not cationic and consequently does not provide a color when tested with the dye test. More representative of the deposition is combing force.

(E)_INSTRUMENTAL ANALYSIS OF COMBING FORCE

PURPOSE

Determine the force needed to comb wet and dry hair tresses treated with 0.5% active quaternium compound by instrumental analysis.

PROCEDURE

TREAT HAIR TRESSES

Treat hair tresses by soaking them in 10-15mL of 0.5% active quat solution for two minutes at 20-25^{o}C.

Rinse hair tresses under running tap water (2.0-2.5 gallons/min, 35-40^{o}C), for one minute. Allow hair tresses to air dry for 24 hours at 20-25oC and 40-50% relative humidity.

RESULTS

Table: 12 Measured Combing Force (grams)

Subject A	1st Combing	2nd Combing	3rd Combing	Average
Blue	10.0	15.0	13.0	12.6
Yellow	25.0	19.0	15.0	19.6
Red	30.0	13.0	13.0	18.6
Green	40.0	38.0	30.0	36.0
Black	12.0	13.0	15.0	13.3
Subject B	1st Combing	2nd Combing	3rd Combing	Average
Blue	25.0	13.0	15.0	17.6
Yellow	29.0	20.0	10.0	19.6
Red	30.0	28.0	20.0	26.0
Green	45.0	40.0	35.0	40.0
Black	25.0	15.0	10.0	16.6
Subject C	1st Combing	2nd Combing	3rd Combing	Average
Blue	10.0	12.0	10.0	10.6
Yellow	15.0	10.0	10.0	11.6
Red	15.0	25.0	20.0	20.0
Green	22.0	24.0	25.0	23.6
Black	30.0	23.0	30.0	27.6
Subject D	1st Combing	2nd Combing	3rd Combing	Average
Blue	10.0	10.0	12.0	10.6
Yellow	35.0	22.0	25.0	27.3
Red	15.0	15.0	10.0	13.3
Green	43.0	40.0	35.0	39.3
Black	20.0	10.0	13.0	14.3
Subject E	1st Combing	2nd Combing	3rd Combing	Average
Blue	27.0	16.0	10.0	15.0
Yellow	40.0	20.0	20.0	26.6
Subject E	1st Combing	2nd Combing	3rd Combing	Average
Red	20.0	20.0	12.0	17.3
Green	38.0	40.0	45.0	41.0
Black	23.0	20.0	15.0	19.3

Table:13 Average Values of Combing Force (grams)

Tress Color	Total Score
Blue	13.20
Yellow	17.02
Red	19.04
Green	35.98
Black	18.22

The instrumental analysis of 0.5% active quat compounds showed that Blue (MMM), performed the best followed by yellow (MMG), black (deionized water), and red (Polyquaternium 10). This confirms the test results that were obtained in part five of this study.

CONCLUSIONS

Quaternium compounds can be classified as hard or soft by their ability to form gelled systems with anionic systems. Cationic systems that form a gel at near stoichiometric amounts are classified as “soft”, those that form precipitates of haze without appreciable viscosity build are classified as “hard” quats. “Soft quats” can produce foam in the systems they gel, albeit at levels below the volume of foam generated by the anionic per se.

Quaternium compounds titrated with sodium laureth sulfate (SLES) produced greater viscosities with amido quats. The exception was amido quats containing a benzyl group, which exhibited a low viscosity in SLES.

Compounds that contained a benzyl group, or were a alkyl rather than amido, (i.e. AMB, AME, AMG, AMM, AEB, AEG), precipitated at lower levels of titration and are consequently classified as “hard quats”.

Overall, all quat/anionic solutions tested had less foam than when the anionic itself was tested. This was true for both SLS and SLES.

With the exception of quats AEG, AMG, and CaMG, and the negative control, all 0.5% active, aqueous solutions of quaternium compounds produced positive results for cationic substantivity, when evaluated per se.

In aqueous solutions of anionic surfactants, all quat solutions, including the positive control (polyquaternium 10), produced negative results. This is thought to be due to the fact that there is no net positive charge of the hair, due to the fact that the anionic and cationic in combination have a new zero charge. This is not to be confused with no deposition. Instrumental dry combing analysis of human hair tresses treated with aqueous quat solutions confirmed conditioning, showing that quat MMM indeed performed the best, followed closely by MMG, polyquaternium 10, and the negative control. Again, quat DMG did not show any improvement in performance.

Quat AMB concluded to be the poorest performer yielding opaque surfactant mixtures in part one at low levels. Foam height and stability was dramatically suppressed in part two. Although AMB was substantive to human hair when delivered from an aqueous solution, no substantivity was observed from an anionic mixture.

Quat MMM concluded to be the best performer, yielding a thick, translucent gel with a viscosity well over 10,000 cps for both SLS and SLES titrations. MMM/Anionic Solutions produced an above average foam height without suppression and extended foam stability well over 24 hours or, ten times greater than SLS and SLES, controls, and positive controls (polyquaternium 10 and SLS/SLES). MMM performed equally as well in substantivity tests when delivered from an aqueous system. Like all other quat solutions, no substantivity was observed when delivered from an anionic mixture. Because of its performance, MMM was chosen for subjective and combing analysis. Like quats DMG and MMG, quat MMM performed poorly in the wet combing test of part V. However, it did perform slightly better in the dry combing test. Quat MMM turned out to perform the best in the instrumental analysis of combing force, part VI. The average performance of quat MMM was superior to all quats in this study, including the positive control, polyquaternium 10.

References

1. R.G. Pearson, *J Am Chem Soc*, **85**, 335 (1963).

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